

OZONE BIOMONITORING GARDEN STUDY



THEME: Ozone Garden and the Effects of Air Pollution

BEST TIME TO PLAN TRIP: Early Fall

Unit Rationale

Scientists have noticed that ground level ozone levels tend to be worse at higher elevations, especially at night. Because of this, it is important to monitor ozone levels at various elevations. Purchase Knob is a high elevation site within the park. One of the methods we use to monitor the effects of ozone pollution is to periodically check how certain sensitive species of plants are reacting to ozone exposure. During the study students will be able to understand what ground level ozone is and how it affects plants and animals, and assist in collecting data from a specific plant in the ozone biomonitoring garden.

NORTH CAROLINA CURRICULUM CORRELATIONS

NORTH CAROLINA EARTH/ENVIRONMENTAL SCIENCE ESSENTIAL STANDARDS

Essential Standard EEn.2.2 Understand how human influences impact the lithosphere

EEn.2.2.1 Explain the consequences of human activities on the lithosphere past and present.

EEn.2.2.2 Compare the various methods humans use to acquire traditional energy sources.

Essential Standard EEn.2.5 Understand the structure of and processes within our atmosphere

EEn.2.5.1 Summarize the structure and composition of our atmosphere.

EEn.2.5.5 Explain how human activities affect air quality.

Essential Standard EEn.2.7 Explain how the lithosphere, hydrosphere, and atmosphere individually and collectively affect the biosphere.

EEn.2.7.1 Explain how abiotic and biotic factors interact to create the various biomes in North Carolina

EEn.2.7.2 Explain why biodiversity is important to the biosphere.

EEn.2.7.3 Explain how human activities impact the biosphere.

Essential Standard EEn.2.8 Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth.

EEn.2.8.4 Evaluate the concept of “reduce, reuse, recycle” in terms of impact on natural resources.

NORTH CAROLINA BIOLOGY ESSENTIAL STANDARDS

Essential Standard Bio.1.1 Understand the relationship between the structures and functions of cells and their organelles.

Bio.1.1.1 Summarize the structure and function of organelles in eukaryotic cells (including the nucleus, plasma membrane, cell wall, mitochondria, vacuoles, chloroplasts, and ribosomes) and ways that these organelles interact with each other to perform the function of the cell.

Essential Standards Bio.2.1 Analyze the interdependence of living organisms within their environments

Bio.2.1.1 Analyze the flow of energy and cycling of matter (such as water, carbon, nitrogen and oxygen) through ecosystems relating the significance of each to maintaining the health and sustainability of an ecosystem.

Bio.2.1.2 Analyze the survival and reproductive success of organisms in terms of behavioral, structural, and reproductive adaptations.

Bio.2.1.3 Explain various ways organisms interact with each other (including predation, competition, parasitism, mutualism) and with their environments resulting in stability within ecosystems.

Essential Standards Bio.2.2 Understand the impact of human activities on the environment (one generation affects the next).

Bio.2.2.1 Infer how human activities may impact the environment.





Bio.2.2.2 Explain how the use, protection and conservation of natural resources by humans impact the environment from one generation to the next.

AP BIOLOGY GOALS AND OBJECTIVES

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.

1.01 The learner will identify questions and problems that can be answered through scientific investigations.

1.02 The learner will conduct scientific investigations to answer questions about the physical world.

1.03 The learner will formulate and revise scientific explanations and models using logic and evidence

1.04 The learner will apply safety procedures in the laboratory and in field studies.

Competency Goal 6: The learner will develop an understanding of the unity and diversity of life.

6.05 The learner will examine the structure and function of plants and animals.

Competency Goal 7: The learner will develop an understanding of basic ecological principles.

7.01 The learner will analyze population dynamics.

7.02 The learner will examine the actions and interactions of communities and ecosystems.

7.03 The learner will assess current global issues.

AP EARTH AND ENVIRONMENTAL SCIENCE (APES) GOALS AND OBJECTIVES

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.

1.01 The learner will identify questions and problems in the earth and environmental sciences that can be answered through scientific investigations.

1.02 The learner will conduct scientific investigations to answer questions related to earth and environmental science.

1.03 The learner will formulate and revise scientific explanations and models using logic and evidence.

1.04 The learner will apply safety procedures in the laboratory and in field studies.

1.03 The learner will formulate and revise scientific explanations and models using logic and evidence.

1.04 The learner will apply safety procedures in the laboratory and in field studies.

Competency Goal 2: The learner will build an understanding of the interdependence of Earth's systems.

2.04 The learner will investigate the atmosphere.

2.05 The learner will investigate the biosphere.

Competency Goal 4: The learner will build an understanding of the distribution, ownership, use and degradation of renewable and nonrenewable resources.

4.04 The learner will analyze biological resources.

4.06 The learner will analyze land types and uses.

Competency Goal 5: The learner will build an understanding of air, water and soil quality.

5.01 The learner will analyze the sources of major pollutants.

5.02 The learner will investigate the effects of pollutants.

5.03 The learner will analyze and investigate pollution reduction, remediation and control measures.

5.05 The learner will analyze impacts on human health.

Competency Goal 6: The learner will build an understanding of global changes and their consequences.

6.01 The learner will investigate human effects and consequences on the atmosphere.

Competency Goal 7: The learner will build an understanding of environmental decision making.

7.03 The learner will recognize significance of major environmental laws and regulations: regional, national and international.

7.04 The learner will develop an awareness of environmental options.





TABLE OF CONTENTS

Activity	Page
Unit Rationale/State Learning Standards	1-2
Table of Contents	3
Planning your Trip and Safety Considerations.....	4
Background Information.....	5
Map to Purchase Knob.....	6
Pre-Site Activities	
Vocabulary and Definitions and Instructions	7-8
The Leaf Game	9
Ozzy Ozone.....	10
On-Site Activity	
Park Ranger Directed Lessons: Ozone Garden Biomonitoring Study.....	11
Post-Site Activities	
Effects of High Ozone Levels on Plants Graphing Activity	12-14
Effects of High Ozone Levels on Plants Graphing Activity Answer Key	15
Analyzing Ozone Data Activity	16-17





PLANNING A SUCCESSFUL TRIP

SCHEDULE FOR A DAY OF ACTIVITIES IN GREAT SMOKY MOUNTAINS NATIONAL PARK AT PURCHASE KNOB

- Meet park ranger at Purchase Knob
- Use rest rooms
- Large group introduction
- Break into two groups
- Participate in activities
- Lunch
- Switch groups
- Large group conclusion

- Check the weather before you go. Lunch will be eaten outside.

- School buses can park at the program site.

- The pre-visit activities included in this packet are specific to the theme of your program and should be presented prior to your scheduled visit. The post-visit activities are designed to reinforce and build upon the park experience.

- A map to the Appalachian Highlands Science Learning Center Purchase Knob can be found on page 7

- All students, teachers, and chaperones will meet the park rangers at the Appalachian Highlands Science Learning Center at Purchase Knob.

- The maximum number of students for this trip is 60. We require an adult or teacher for every ten students to create a positive and rewarding experience. The on-site instruction is conducted by a park ranger. However, your assistance is needed with discussion and discipline. Please feel free to contact the park at (828) 926-6251 if you have any further questions.

•Dressing for the Weather

Please remind your students to wear appropriate footwear and clothing for an extended outdoor program. Short pants, flip flops, or sandals are not recommended. Temperatures in the mountains can be 10-15 degrees colder than at your school. You may wish to alter portions of the program should inclement weather appear.

•Restrooms and Water

Restrooms and water fountains will be available at the program site.

•Lunch

Lunches will be eaten picnic style on the grounds of the Learning Center. Lunches should be put in a box for storage and kept on the bus until needed. Lunches, snacks, and drinks should be provided by the students. There are no concessions at Purchase Knob.

•Safety

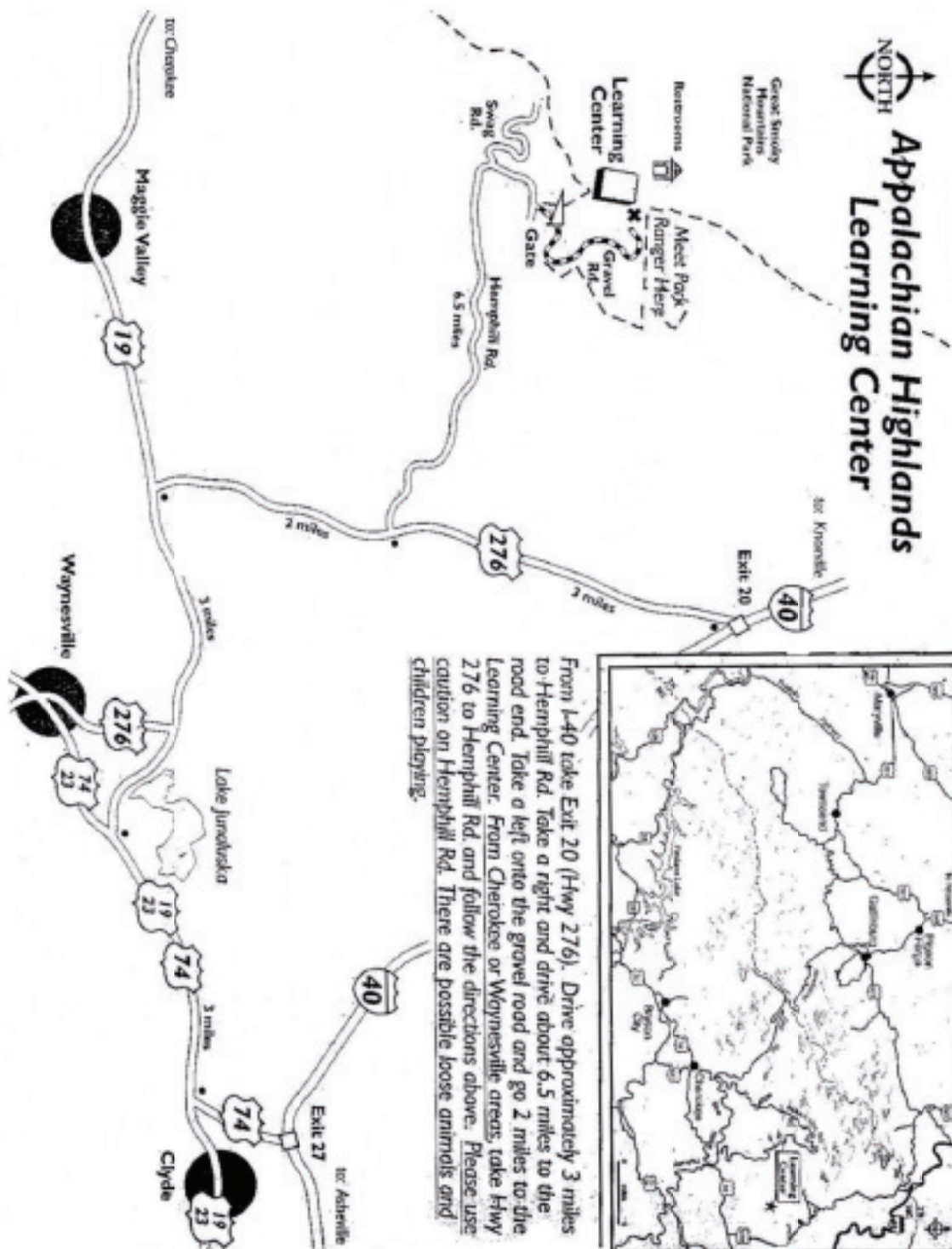
Purchase Knob is a remote location, far from any medical facilities. Students will spend most of their time away from buildings, so please bring a cellular phone. Notify the park ranger of any special concerns or medical conditions including students with allergies, asthma or other medical conditions.

•Cancellation

Should anything unforeseen occur preventing you from keeping your appointment, please contact the park at (828) 926-6251 to notify us of your late arrival or cancellation.



MAP TO PURCHASE KNOB





BACKGROUND INFORMATION

Park Description:

The National Park Service is charged with the management and preservation of the nation's most precious natural and cultural resources. These resources are woven into our natural heritage, and they provide opportunities for recreation, appreciation of beauty, historical reflection, cultural enrichment, and education.

Great Smoky Mountains National Park is one of the largest protected land areas east of the Rocky Mountains. With over 500,000 acres (800 square miles) of forest, the Smokies contain an enormous variety of plants and animals. In terms of biological diversity, a walk from a mountain's foot to its peak is comparable to the 2,000 mile hike on the Appalachian Trail from Georgia to Maine.

Because the National Park Service is charged with protecting resources and natural systems, the park engages in comprehensive research programs, such as air quality monitoring, to foster an understanding of park resources and to show how they are affected by local, regional, and global influences. Since the Smokies are so biologically diverse, the park is designated as an International Biosphere Reserve by the United Nations. The international system contains over 320 reserves in over 80 countries with the primary objectives of conserving genetic diversity and coordinating environmental education, research, and monitoring.

The Smokies also have a rich cultural history. Native Americans have lived in this area for thousands of years, and permanent white settlement began around 1800. The coming of commercial logging around 1900 stripped trees from two-thirds of what is now park land. Established in 1934, the park was created from more than 6,000 tracts of private and commercial land that was bought mostly with money raised and privately donated. Centrally located within a two-day's drive for half of the nation's population, Great Smoky Mountains National Park has the highest visitation of all the national parks in the country.

Purchase Knob Description:

The Purchase Knob property, over 530 acres in size, was donated to Great Smoky Mountains National Park by Katherine McNeil and Voit Gilmore in January 2001. Situated at an elevation of over 5,000 feet, the area contains old-growth forests, mountain meadows and high elevation wetlands. It also rests on geological formations that aren't found anywhere else in the park, lending to a unique and diverse habitat for the study of plants and animals. The house is the location of the Appalachian Highlands Science Learning Center, whose mission is to provide a space for researchers to perform biological inventory and monitoring while offering education programs for students and teachers on these same subjects.



PRE-SITE ACTIVITY

OZONE GARDEN BIOMONITORING INFORMATION



Grade Level: High School

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Applying, Analyzing, Connecting, Contrasting, Demonstrating, Gathering information, Measuring, Reporting, Summarizing

Vocabulary:

- Bioindicator:** vascular or non-vascular plant exhibiting a typical and verifiable response when exposed to a plant stress such as ozone.
- Chlorosis:** yellowing of leaf caused by the loss of chlorophyll needed for photosynthesis.
- Epidermis:** surface layer of cells in a leaf.
- Ground-level Ozone:** an air pollutant that is a result from a chemical reaction between nitrogen oxides and VOCs in the presence of sunlight.
- Necrosis:** localized death of a living tissue.
- Nitrogen Oxides (NO_x):** produced from burning fuels, including gasoline and coal. Nitrogen oxides react with volatile organic compounds (VOCs) to form smog and ground level ozone. Nitrogen oxides are also major components of acid rain.

•**Ozone:** form of oxygen with three atoms of oxygen; a colorless, highly reactive gas that exists from the Earth's surface miles up into the atmosphere.

•**Photosynthesis:** the process by which green plants containing chlorophyll use the energy of sunlight to produce carbohydrate (sugars).

•**Purpling (or Stippling):** most common symptom of ozone damage on specific species of broad leaf plants; discrete and very fine purple colored spots that are seen on the upper side of the leaf's surface.

•**Sulfur Dioxide (SO_x):** a gas produced by burning coal, most notably in power plant and the production of paper. Sulfur dioxide plays an important role in the production of acid rain and haze.

•**Stomata:** tiny openings in a leaf surface through which gaseous interchange takes place.

•**Temperature Inversion:** a weather condition in which a layer of warm air settles over a layer of cold air that lies near the ground.

•**VOCs:** Volatile Organic Compounds - VOCs are released from burning fuel (gasoline, oil, wood, coal, natural gas, etc.), solvents, paints glues and other products used at work or at home. Cars are an important source of VOCs. VOCs combine with nitrogen to form Ozone. Trees naturally give off VOCs; 85% of the VOCs in North Carolina are from natural (or biogenic) sources.

Materials:

- Vocabulary
- Computer(s) with internet accessibility to view website(s)
- Student activity sheet (page 9)

Objectives:

- 1) be able to estimate the percentage of injury on the leaves of various plant species
- 2) become familiar with the vocabulary associated with estimating ozone symptoms on plants (stippling, chlorosis, necrosis)
- 3) become familiar with the natural threats to Spruce Fir Forests

Background:

A website (<http://www.nature.nps.gov/air/edu/O3Training/index.cfm>) has been created by the national park service as a practice for those who will be going out into the field to monitor the effects of ozone pollution on plants. This activity is vital for students to practice to ensure their field activities are both meaningful to them and to the park as valid data.

Relate to the students that during their field trip to Purchase Knob they will be assisting in a research project by collecting data on the amount of visible symptoms they see on plants as a result of ozone exposure. To do this, they will need to practice their estimating skills. While on the field trip, students will be estimating the amount of brownish dots they see on plant leaves (called stippling), the amount of chlorosis (yellowing) and the amount of necrosis (death). When practicing, students should estimate the percentage of leaf that appears as black dots.





Procedure:

Students should work in pairs at computers or view from a large screen as a class. The teacher should first walk the students through an example reading the instructions on the “Leaf Game” activity sheet. Students should record their answers on the activity sheet.

Collect trial results from each student group and compare with actual percentages. Which percentage groups did the class as a whole have the most difficulty with? Which were the easiest? It has been studied that most people do the best job with the outer extremes; did that hold true with the class?

To view the Spruce Fir podcast video go to

<http://www.thegreatsmokymountains.org/eft/10modules.html> Turn the microscope knob that appears on the computer screen to Section 2, A Connected Web. Click “Watch Video” and view video.





THE LEAF GAME

- Open the address <http://www.nature.nps.gov/air/edu/O3Training/index.cfm>
- Change the number of practice leaves to “10,” click “select.”
- Next, click one of the images to practice. Common Milkweed is a good one since it is in color.
- Rate the percent of black dots covering the entire leaf surface. Even though ozone damage does not cross over veins, veins count in the overall percentage of the leaf. Write an “x” in the percentage category that you think is the correct answer.
- Click “OK” after you have selected a percentage and see the answer. Record an “o” in the percentage category of the correct answer.
- Click “next image” to continue the training.

1. Which species did you use? _____

Trial 1

2. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 2

3. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 3

4. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 4

5. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 5

6. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 6

2. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 7

3. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 8

4. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 9

5. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

Trial 10

6. ____ 0% ____ 1%-6% ____ 7%- 25% ____ 26%-50% ____ 51% - 75% ____ 76% - 100%

7. Overall, did you underestimate or overestimate the amount of ozone damage?



PRE-SITE ACTIVITY

OZZY OZONE



Grade Level: High School

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Analyzing, Classifying, Comparing, Connecting, Applying, Assessing, Contrasting, Estimating, Evaluating, Generalizing, Hypothesizing, Interpreting, Predicting, Summarizing

Materials:

- pdf worksheet found on http://www.handsontheland.org/teachers/data/O3_Skills_Center_Student_Worksheet.pdf
- Pencils
- Computer with internet connection to view Ozzy Ozone website <http://www.handsontheland.org/ozone-inquiry>

Learner Objectives:

- 1) recognize what chlorosis, necrosis, and purpling/stippling look like
- 2) learn what chlorosis, necrosis, and purpling/stippling means for the plant
- 3) learn how we know that the purpling/stippling symptoms are from ozone
- 4) practice estimating ozone damage and other symptoms on selected plants

Procedure:

Have students go to the Ozzy Ozone website and choose a date and start looking for ozone-related injury. They can test themselves using the fields listed on the top of the webpage.





ON-SITE ACTIVITY

OZONE GARDEN BIOMONITORING STUDY

Grade Level: High School

Subject Area: Science

Activity time: 75 minutes

Setting: Outside in the park

Skills: Analyzing, Applying, Assessing, Calculating, Charting, Classifying, Collecting information, Comparing, Describing, Estimating, Gathering information, Hypothesizing, Identifying cause and effect, Interpreting, Recording data, Summarizing

Materials:

- Clipboard
- Data sheets
- Pencils
- Meter sticks

Objectives:

- 1) describe two characteristics of ozone damage on plants
- 2) relate which type of chemical pollutant relates to ozone formation
- 3) describe how plants can be monitored for ozone symptoms over time
- 4) explain why plants should be monitored

Background:

One of the types of pollution we research is ground level ozone. For years, scientists have noticed that ozone levels tend to be worse at higher elevations, especially at night. Because of this, it is important to monitor ozone levels at various elevations.

One of the methods we use to monitor the effects of ozone pollution is to periodically check how certain sensitive species of plants are reacting to ozone exposure. A team of researchers, some of whom have been working in this park since 1988, have developed a way to monitor plants for visible effects of ozone pollution. During the study the students will assist the rangers in collecting some of this data.

Procedure:

Everyone will work with a partner to monitor their plant. It is important not to make any assumptions as to why they see something but just to rate what they see on the plant. Students will be estimating the percent of stippling or purpling on the leaf, the percent of yellowing or chlorosis, and the percent of death or necrosis. The students will start collecting data from the base of the plant and note leaves that are missing. The students will collect the data on the data sheets.





POST-SITE ACTIVITY

EFFECTS OF HIGH OZONE LEVELS ON PLANTS

Grade Level: High School

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Analyzing, Classifying, Comparing, Connecting, Applying, Assessing, Charting, Contrasting, Evaluating, Generalizing, Hypothesizing, Interpreting, Predicting, Summarizing

Materials:

- High Ozone Levels worksheet (pages 13-14)
- High Ozone Levels worksheet answer key (page 15)
- Pen/pencil

Objectives:

- 1) analyze previously recorded data
- 2) determine the appropriate type of graph to use to illustrate the data
- 3) draw conclusions based on analysis of the graph and the table

Background:

The Ozone Biomonitoring Garden section of the Hands on the Land website allows students to compare their data with previously recorded daily ozone levels at Purchase Knob. This enables the park rangers and thus the students to draw conclusions from the recorded data.

Procedure:

The students should create a graph using data listed on the data sheet. Students should be able to determine which type of graph (line, bar, pie chart...) will best illustrate the story the data tells. Students should draw conclusions based on the data from the graph and Table 1.1.

Have students share their graphs and final conclusions with the entire class. As a group, determine if there are any other conclusions that can be drawn from the analysis. If not, what additional information would you like to have? How can you get that information?





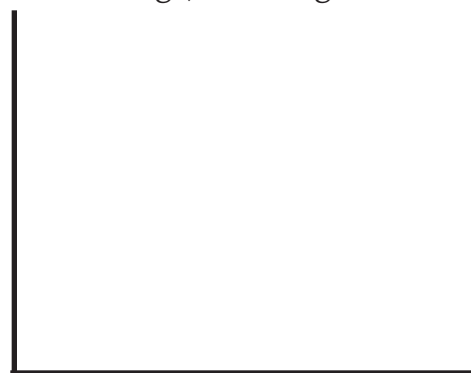
EFFECTS OF HIGH OZONE LEVELS ON PLANTS

GRAPHING EXERCISE

1. Graphing Exercise

Listed below are the following 8 days of 1 hour Ozone averages over a 14 day period. Use an appropriate graph to graph the data (Line, x-axis = date, y-axis = 1 hour ozone average) to the right of the data

Date	1 Hour Ozone Average (in parts per billion)
7/10/08	40 ppb
7/13/08	54 ppb
7/14/08	61 ppb
7/15/08	69 ppb
7/18/08	87 ppb
7/20/08	98 ppb
7/22/08	58 ppb
7/23/08	62 ppb

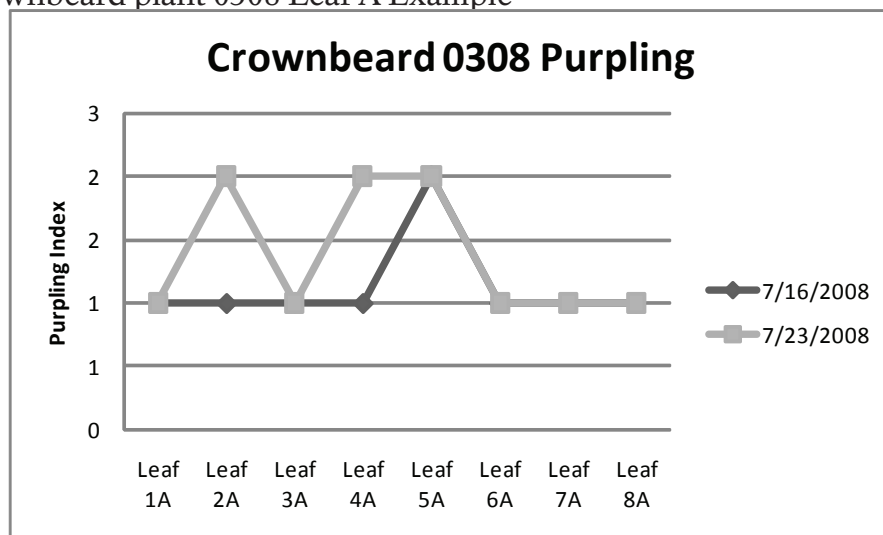


2. Table 1.1: Effects of High Ozone Level Days on Crownbeard Plants

Purpling Foliar Area Injury (measured in percent): 1 = 0, 2 = 1-6, 3 = 7-25, 4 = 26-50, 5 = 51-75, 6 = 76-100 (NPS scale)

	Crownbeard 0308		Crownbeard 0408	
	7/16/08	7/23/08	7/16/08	7/23/08
Leaf 1B	1	6	2	3
Leaf 2B	1	2	2	5
Leaf 3B	1	3	2	4
Leaf 4B	1	2	2	5
Leaf 5B	1	2	1	2
Leaf 6B	1	1	1	1
Leaf 7B	1	1	1	1
Leaf 8B	1	1	1	1

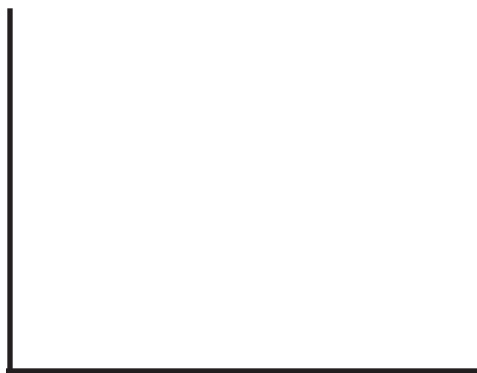
Crownbeard plant 0308 Leaf A Example





2. Graph the purpling foliar area injury on the following Crownbeard plants 0308 Leaf B and 0408 Leaf B. Crownbeard plant 0308 Leaf A is shown on the previous page as an example. Remember to label the axes, supply a legend, and give each graph a title

a. Crownbeard plant 0308 Leaf B Graph



b. Crownbeard plant 0408 Leaf B Graph



3. Using the graphs you created from Questions #1 and #2 and the information in Table 1.1 to describe the relationship between 1 hour ozone levels and Crownbeard purpling. Analyze what happens to leaves 1-8 on all three plants. State your findings below.

EFFECTS OF HIGH OZONE LEVELS ON PLANTS

GRAPHING EXERCISE ANSWER KEY

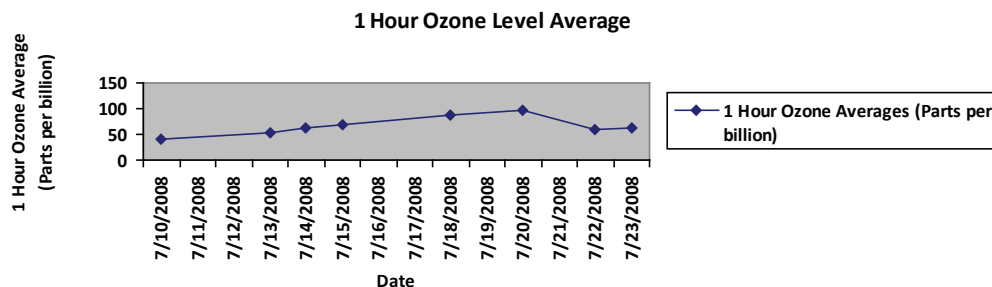


1. Graphing Exercise

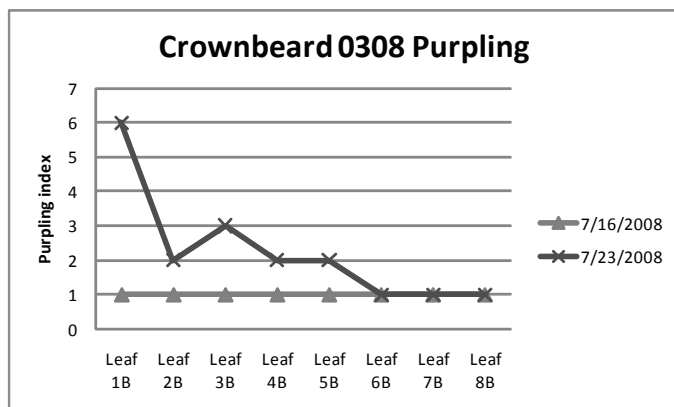
Listed below are the following 8 days of 1 hour Ozone averages over a 14 day period. Use an appropriate graph to graph the data (Line, x-axis = date, y-axis = 1 hour ozone average) to the right of the data

Date 1 Hour Ozone Average (in parts per billion)

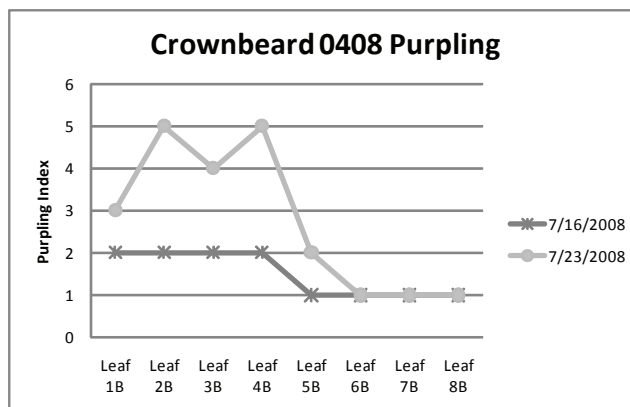
7/10/08	40 ppb
7/13/08	54 ppb
7/14/08	61 ppb
7/15/08	69 ppb
7/18/08	87 ppb
7/20/08	98 ppb
7/22/08	58 ppb
7/23/08	62 ppb



2. a.



b.



3. Using the graph you created and the information in Table 1.1, describe the relationship between 1 hour ozone levels and Crownbeard purpling. Analyze what happens to leaves 1-8 on all three plants. State your findings below.

The greater the amount of ozone air pollution present, the more foliar injury that will likely be observed on ozone sensitive plants such as Crownbeard. The amount of foliar (leaf) injury is likely to increase shortly after days with high levels of ozone air pollution. During the days of 7/18/08 and 7/20/08 ozone increased. Crownbeard leaves that had had light (category 1-2) purpling (stippling) on the 16th were damaged, and we can see the effects on the 23rd, 3 days later.



POST-SITE ACTIVITY

ANALYZING OZONE DATA

Grade Level: High School

Subject Area: Science

Activity time: 45 minutes

Setting: Classroom

Skills: Analyzing, Classifying, Comparing, Connecting, Applying, Assessing, Charting, Contrasting, Evaluating, Generalizing, Hypothesizing, Interpreting, Predicting, Summarizing

Materials:

- Graph paper
- Pencils
- Computer with internet connection to view website for the Ozone Bio-monitoring Garden
http://www.handsontheland.org/monitoring/projects/ozone/ozone_bio_search.cfm
- Analyzing Ozone Teacher Page

Learner Objectives:

- 1) analyze data collected during the field trip by comparing it with previous data
- 2) determine the appropriate type of graph to use to illustrate the data
- 3) draw conclusions based on analysis
- 4) determine what information is still needed or other limitations of the study

Procedure:

Explain to students that after the field trip, park rangers checked their data sheets and entered their data into the online database. The Ozone Biomonitoring Garden section of the Hands on the Land website allows them to compare their data not only to previous data at Purchase Knob but also to gardens located in other areas. Ask students what differences they might see between an urban and rural area and between a high and low elevation area.

Allow students to choose how they would like to analyze the data using the Hands on the Land website. They can compare data by following one leaf on a particular plant over the growing season. Another comparison could be tracking one entire plant over the growing season or over several years. A third comparison could be to compare one or two plants from different gardens to see if there is a difference because of elevation or urban/rural location.

Create a graph using data from the Hands on the Land website. Determine which type of graph (line, bar, pie chart...) will best illustrate the story the data tells. Draw conclusions based on the data. Determine what additional information would be useful to better answer questions that have come up.

Have students share their graphs with the entire class. As a group, determine if there are any conclusions that can be drawn from the analysis. If not, what additional information would you like to have? How can you get that information?



ANALYZING OZONE DATA TEACHER PAGE

DATA ANALYSIS INSTRUCTIONS



- 1) Go to the database website
http://www.handsontheland.org/monitoring/projects/ozone/ozone_bio_search.cfm
- 2) In the datasheet section, select “Purchase Knob” from the drop down menu
- 3) To look at data, click the review button.
- 4) The data is sorted by plant ID name (the second column). The initials stand for the following species:
BB = Blackberry CB = Crownbeard CF = Coneflower EB = Elderberry
CFD = Coneflower var. digitalis (Purchase Knob only) MW = Milkweed
- 5) The data is then arranged with the most recent entry at the top of the list for each plant. Each plant species is labeled with four numbers: CB0105 stands for Crownbeard, plant 01, year 2005. Plant CB0104 stands for Crownbeard, plant 01, year 2004.
- 6) To review data for a particular plant and day, click the data button to the right of the screen.
- 7) When reviewing the data, remember that leaf 1 is the lowest leaf on the plant; leaf 8 would be towards the top.
- 8) Have students compare their data to other data on the Hands on the Land website by reviewing data from other gardens. To do this, go back to the home page for the garden study and scroll down to the section titled “reports, graphs and maps.” In the “compare up to four datasets from garden” section, select “Purchase Knob” from the drop down menu and click on the graph button. You will need to select some parameters to compare. Try the following:
 - a) Under “comparison 1,” use the drop down menu to select “Cradle of Forestry” and then click the button that says “choose sites.” This garden is located in the Pisgah National Forest and is a mid-elevation site.
 - b) Use the drop down menu under each garden location to select any plant, but be sure to compare the same species in each garden.
 - c) Select leaf #4 for each garden and don’t change “a” next to “leaf.”
 - d) Next to injury, use the drop down list in each garden to select purpling. This is what we call ozone injury. Click the “graph” button.
- 9) Compare data by following one leaf on a particular plant over time. To do this, follow the instructions below.
 - a) On the home page for the garden study, in the section titled “reports, graphs and maps,” find the “animate a plant’s foliar injury over time.” Use the drop down list to select “Purchase Knob” and click the “graph” button.
 - b) To view the animation, pick a plant from the drop down list next to “plant ID.” A good example is CF0904. Click the “graph” button.
 - c) Use the scroll bar under the picture of the plant on the left side of the box. As you slide the scroll bar, you will see the various types of injury on the plant change over time.
 - d) Have the students look at several different plants.

The only injury that is directly related to ozone exposure is the purple color. Necrosis and chlorosis are caused by a variety of factors including insect damage, nutrient deficiencies, drought or too much water.

